

April 28, 1995



Wallace Smith
Office of Naval Research
Code 332 (SMITH) Room 504
800 North Quincy Street
Arlington, VA 22217-5660

Dear Wally:

Enclosed please find our six month report (7/94-12/94) on the Production of Distorted 3-3 Hydrophone Composites from Reticulated Ceramics, Contract # N00014-94-C-0046.

Like our previous report, progress is reported using the same phases, tasks and time lines described in our initial proposal. The performance optimization task of the contract has been slower than anticipated and hence the addressing of certain scale-up manufacturing concerns has been delayed.

As we discussed at the Penn State ONR Workshop in April, we have made significant progress in early 1995 in improving performance. In a qualitative sense we have shown good hydrostatic response and high capacitance with a low density cost effective material. As per your recommendation we will be meeting with the NUWC personnel in early May to discuss potential applications. We are also initiating discussions with Lockheed Martin on towed array devices. We will devote some of our remaining efforts on prototype configurations defined in conjunction with these systems people.

We feel the overall contract goals are attainable and look forward to continuing our efforts over the next six months with ONR and Alfred University.

Sincerely,

D. Andrew Norris
D. Andrew Norris
Development Engineer

c: DCMO - Buffalo
Director, Naval Research Laboratory
Defense Technical Information Center
Walter Schulze, NYSCC at AU

enclosure

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PHASE I - PERFORMANCE OPTIMIZATION

PROGRESS:

Test coupon manufacturing was a main focus over the six month period from 7/94 to 12/94. Samples were processed by Hi-Tech Ceramics and then supplied to Alfred University for firing, electroding and testing. Previously supplied samples encompassed: four pore sizes (15,30,45 and 65 ppi), undistorted and 2:1 aspect ratio distorted foam, two densities (10 and 15%), face coated and non-face coated reticulate. The samples supplied during the current reporting period included the same four pore sizes but of an increased, 3:1 aspect ratio, degree of distortion. Web coating of the 3:1 foam was more difficult since the greater distortion results in a more dense structure to impregnate and coat with slurry. The 15ppi, 3:1 distorted foam processed to approximately 15% density gave webs of good integrity and resulted in an increase in d_h over the 2:1 distorted foams. Over forty samples of this pore size and distortion have been supplied to Alfred University for evaluating alternate epoxy materials and electrodes for the 3-3 composites.

Composite properties obtained have been reported by Matt Creedon and Walter Schulze of the New York State College of Ceramics at Alfred University during presentations at the ISHM '94 and ISAF '94 conferences. Included in these reports was the pressure stability of these Distorted 3-3 Hydrophone Composites when a stiff epoxy matrix such as Spurrs is used. Alternate epoxies and epoxies with glass and polymer microspheres to modify stiffness are currently being tested. PZT reticulate with 5:1 aspect ratio has been processed but unsuccessfully fired. Additional slurry modifications will be needed to coat these extremely distorted foams, especially of the finer pore sizes.

The goal of the test coupons has been to determine the specific parameters for the six 3-3 composite panels to be supplied to the Navy for testing at the conclusion of the contract. These specifics should be decided upon during the first half of 1995 by continued testing and discussion with contract advisors.

ACTION ITEMS:

Coupon manufacturing and testing will continue with emphasis placed on narrowing down the candidates for the final composite panels. The 5:1 distorted structure and alternate epoxies and modifiers still need to be evaluated as well as a 3-3 PZT/air composite with a stiff electrode before an adequately researched decision can be made.

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PHASE II - PANEL ASSEMBLY

PROGRESS:

Discussion concerning the panel assembly will begin in early 1995. The epoxies, fillers and electrode materials to be used are being evaluated as part of the PHASE I activity. The d_h response, component durability and ease of assembly are three of the parameters that will be reviewed before deciding the specifics of the panel design.

ACTION ITEMS:

Processing of the panels will occur in the second half of 1995 along with documenting the procedures used for their assembly and determining the requirements for large scale manufacturing of the same.

PHASE III - MANUFACTURING ASSESSMENT

PROGRESS:

Hi-Tech Ceramics has fabricated at its facility a manufacturing scale foam stretcher for distorting the as-received polyurethane foam. The thermal-mechanical distortion process involves heating the foam above its softening point to approximately 180 C, stretching it in a controlled manner and then cooling it to set the now elongated structure. The stretcher is modeled after the prototype unit used for the initial distortion trials by researchers at the New York State College of Ceramics at Alfred University.

The foam stretcher comprises a 30 gallon insulated drum surrounded by a resistance heating source with appropriate temperature controls. Two custom designed grips hold the foam without slippage during distortion inside the heated zone and extend outside the drum to the surrounding support frame. The support frame is adjustable to separate the clamps while attached to the ends of the foam blank. The resultant load on the foam is detected by a crane scale. Figure 1 shows pictures of the foam stretcher. The temperature and applied load are manually controlled and monitored which provides greater flexibility than a fully automated system while the distortion process limits and methodology are being developed. Both temperature and rate of loading can be automated once the specifics for stretching foam are determined. Pore sizes of 65, 45, 30, and 15ppi (pores per inch) can now be reproducibly distorted up to a cell aspect ratio of 5:1. Sample sizes of up to a foot in length and 4"X4" cross section are possible.

Hi-Tech is awaiting delivery of a furnace purchased as part of this phase for in-house firing of PZT. Currently all firing is still done at NYSCC AU.

ACTION ITEMS:

Foam stretch runs will continue to be done to smooth out the process. Automating this step will be considered. Alternate methods of producing PZT reticulate components such as cutting down larger pieces to several small components or trying other shapes besides plates will be tried as a way of designing for specific hydrophone applications. Material handling issues such as waste and recycling techniques will be addressed as the larger sized panel components are processed. Also, specialty saggers will be fabricated for firing PZT during this phase.

PHASE IV - PROGRAM MANAGEMENT

PROGRESS:

Group meetings between Hi-Tech Ceramics and Alfred University were held on an as needed basis to review progress and set directions. Most communication was on a more frequent weekly to bi-weekly basis by telephone and laboratory visits as various processing changes were made by Hi-Tech and the final component response measured by the University researchers. Copies of the minutes from the group meetings held from 7/94 - 12/94 are contained in Appendix A.

Appendix A also contains a graph of contract spending versus the budget through December 1994.

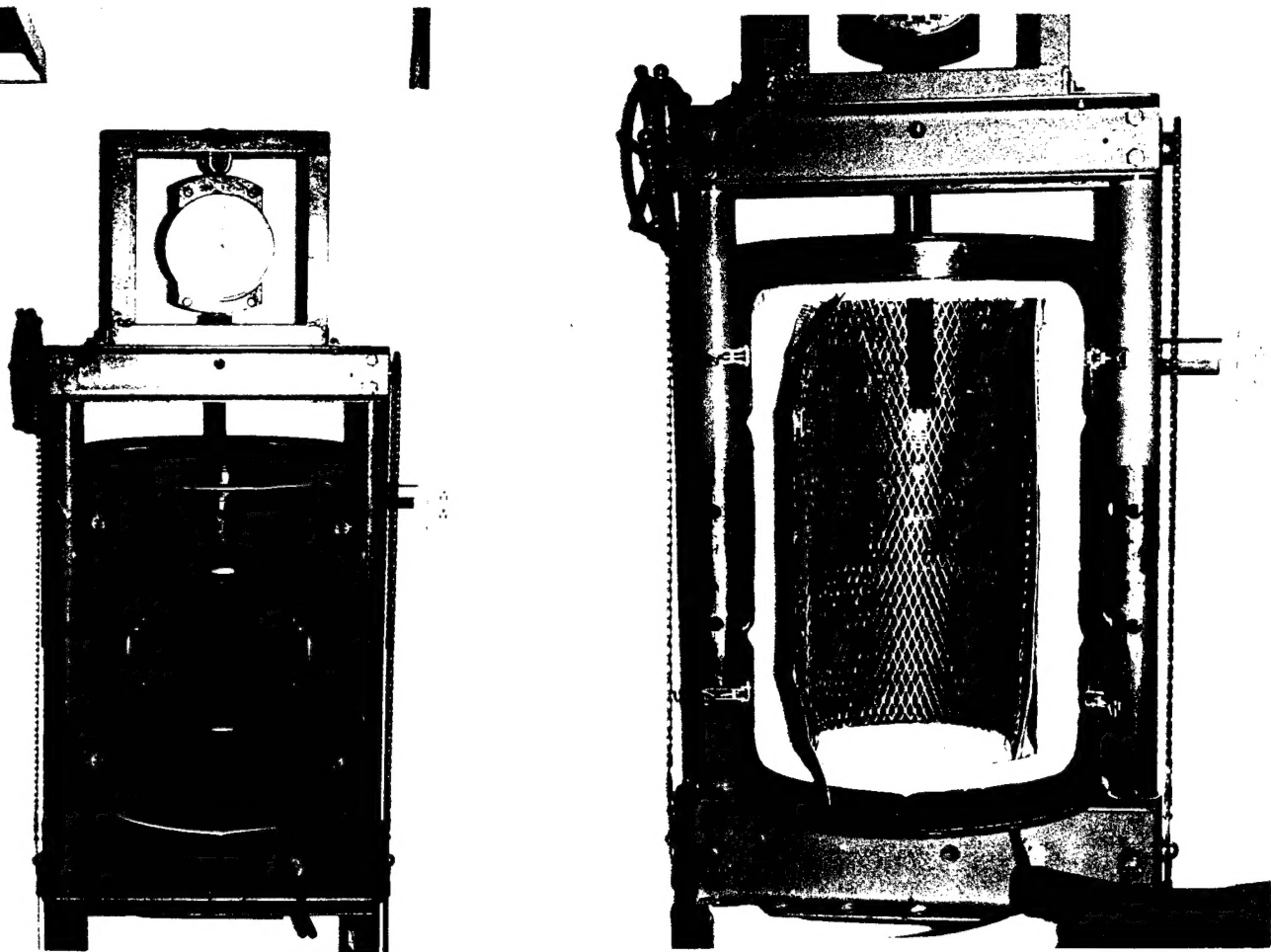


Figure 1. Exterior and Interior view of foam stretcher. Grips not shown in photos.

APPENDIX A

ONR Contract Meeting Summary
8/4/94

Attendees: Matt Creedon, Andy Norris, ^{on 8/4/94} Sudhakar, Truett Sweeting,
Rick Utt.

This meeting was for Matt to do a practice run of his presentation for the International Symposium on Applications of Ferro electrics (ISAF) at Penn State on August 8 - 11, and to introduce Rick Utt, the new Hi-Tech Ceramics technician, to the ONR project. Matt's presentation was a good introduction for Rick to PZT hydrophone composites. The presentation was similar to his ACerS one, but with some additional comments made by Matt about face coated test pieces and samples with greater distortion currently being analyzed.

The increased stretch samples with approximately 3:1 aspect ratio were processed and will be fired by Matt after he returns from Penn State on 8/12/94. These samples are 65, 45 and 30 ppi. Andy will supply Matt with 15 and 10 ppi foam for stretching. Matt's comments about the increased stretching were that the webs do not seem to be thinning down, that the structure seems to be just distorting so we may still be able to stretch further than 3:1.

Initial test results of the face coated samples showed no noticeable improvement. This may be due to the epoxy being so stiff that there is no benefit to a hard electrode surface. Testing of the face coat will be continuing with the 3:1 stretched pieces. It currently takes 2 - 3 hours to stretch one piece of foam and any possible time savings should be incorporated into the manufacturing scale stretcher to be made at Hi-Tech.

Action items:

Matt to fire 3:1 stretched samples for testing

✓ Andy to supply 10 and 15 ppi foam for stretching to Matt

Andy to process increased stretch (3:1) samples with face coat

cc: Jeff Morris
Walter Schulze



**HI-TECH
CERAMICS, INC.**

ONR CONTRACT MEETING SUMMARY

SEPTEMBER 8, 1994

Attendees: ^{Jeff Morris} Matt Creedon, Andy Norris, Sudhakar, Truett Sweeting, Walter Schulze

This meeting was held to review some difficulties Matt has had firing the 3:1 stretched samples and address concerns about non-uniformities in the 3:1 coated structures.

Samples of 3:1 stretched foam, 30, 45 and 65ppi were processed to approximately 15% density and supplied to Matt for firing and analysis. The 65 and 45ppi showed cracking and the 30ppi tended to disintegrate when fired. Adjusting the firing rate showed no improvement. The uniformity of these samples was not as good as the 2:1 samples previously supplied. The 3:1 samples will be remade with attention to directionality during spin-out and possibly increased binder to aid uniformity. The 3:1 stretched structure tends to hold slurry in the "palms" of the cells during deposition creating a non-uniform structure. Matt was able to get one good piece from each pore size to test d_{33} and d_h . Foam for 10 and 15ppi has also been stretched to 3:1 and will be processed at Hi-Tech.

Suda has sent samples of four different impregnation mediums (Spurrs, Ecogel, Polyurethane and Epotech) to K.B. Aerotech to have the Poisson's ratio measured. Panametrics is a company sending transducers to Suda so he can measure Poisson's ratios at AU for various epoxies. Spurr's is the impregnating epoxy we currently use yet may be too stiff while the Ecogel may be too soft. Suda's work will isolate a more optimum stiffness epoxy for impregnating, cutting and stress transfer with these PZT composites.

Matt will be presenting a paper at the ISHM Conference in November and hopes to have complete d_{33} and d_h characterization for the 3:1 stretched composites to compare with the 2:1 and undistorted previously reported on.

ACTION ITEMS:

- Andy to remake 30, 45, and 65ppi 3:1 15% dense samples with process changes to aid uniformity.
- Andy to process 10 and 15ppi 3:1 15% dense samples.
- Matt to test 3:1 stretched 30, 45, and 65ppi he was able to fire successfully.
- Suda to follow up with Aerotech epoxy testing and begin in-house measurement of epoxy stiffness with Panametric transducers.
- Rick Utt to continue work on Hi-Tech foam stretcher

c: Jeff Morris
DAN/jg

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ONR CONTRACT MEETING SUMMARY
NOVEMBER 11, 1994

ATTENDEES: Matt Creedon
Andy Norris
Dr. Sudhakar
Truett Sweeting

ORDER OF BUSINESS:

This meeting was held so Matt could do a practice run of his ISHM presentation for next weeks conference in Boston. The electrical characterization results of the 3:1 aspect ratio samples were also discussed as this information was new to Hi-Tech.

One of Matt's conclusion was that the 3:1 stretch continues to increase the hydrostatic dielectric response over that of the zero and 2:1 aspect ratio stretched foam. Areas to focus on are the web coating uniformity and completeness on the 3:1 samples which are visually inferior to the previous samples of lower stretch ratio. Although d_h continues to increase with greater stretching, Matt and Suda hope to enhance that increase with the use of a more optimum stiffness epoxy. Hi-Tech will supply 20 samples of 15 ppi stretched material for the specific evaluation of the various epoxies Suda has been testing.

Matt will be gone 11/15 - 11/17 at the ISHM conference in Boston.

ACTION:

- *Andy to supply 20, 15 ppi 3:1 stretched samples to AU for epoxy tests.
- *HTC to fabricate another sintering box for Matt
- *Matt, Suda to test epoxies.

Respectfully submitted,

D. Andrew Norris
D. Andrew Norris

cc: Jeff Morris
Walter Schulze

DAN/kro

ONR BUDGET vs ACTUAL 1994

